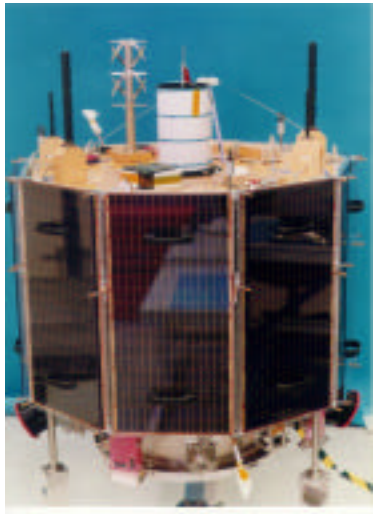
Internet in Space with UoSAT-12

Operating Missions as Nodes on the Internet (OMNI)

http://ipinspace.gsfc.nasa.gov/



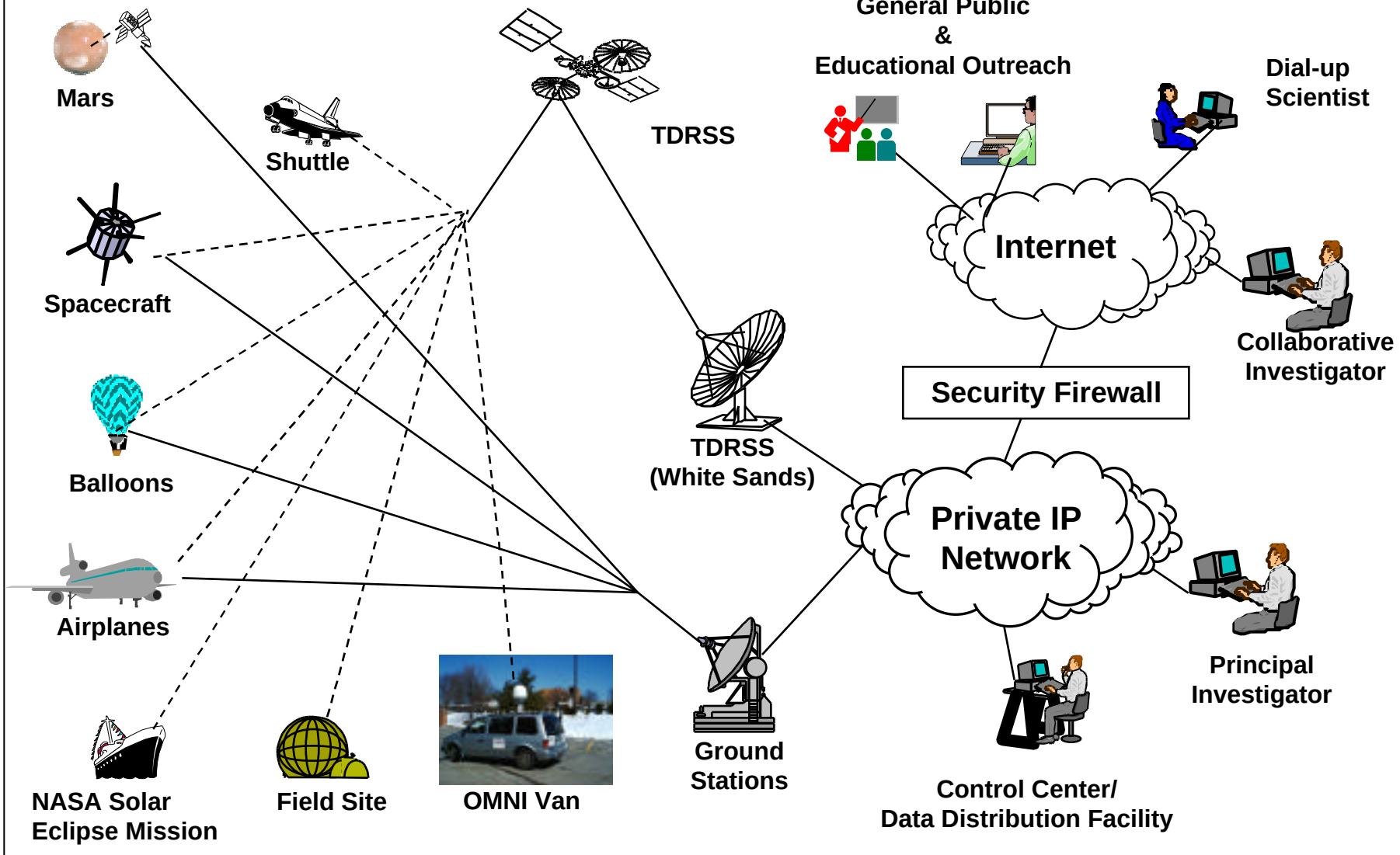
James Rash
NASA/GSFC

November 13, 2000

Summary

- **Overall Concept of Internet in Space**
- **Experiment Team**
- **Purpose of Experiments**
- **UoSAT-12 Satellite**
- **Experiment Setup**
- **Experiment results**
  - Ping Experiment
  - Clock Synch Experiment
  - File Transfer Experiment
  - Performance Experiment
- **Conclusions**
- **Future**

Space Internet Communication Concept



UoSAT-12 Flight Experiment Team

- **NASA/GSFC**
  - James Rash
- **Computer Sciences Corp**
  - Keith Hogie, Ron Parise, Ed Criscuolo, Jim Langston
- **Surrey Satellite Technology Ltd. (SSTL)**
  - Chris Jackson
- **VyTek Wireless**
  - Harold Price

Purpose of UoSAT-12 Experiments

- **Address the question:**
  - Which standard RFC-compliant Internet protocols can support LEO space mission communications?
- **Obtain performance data**

UoSAT-12 Satellite

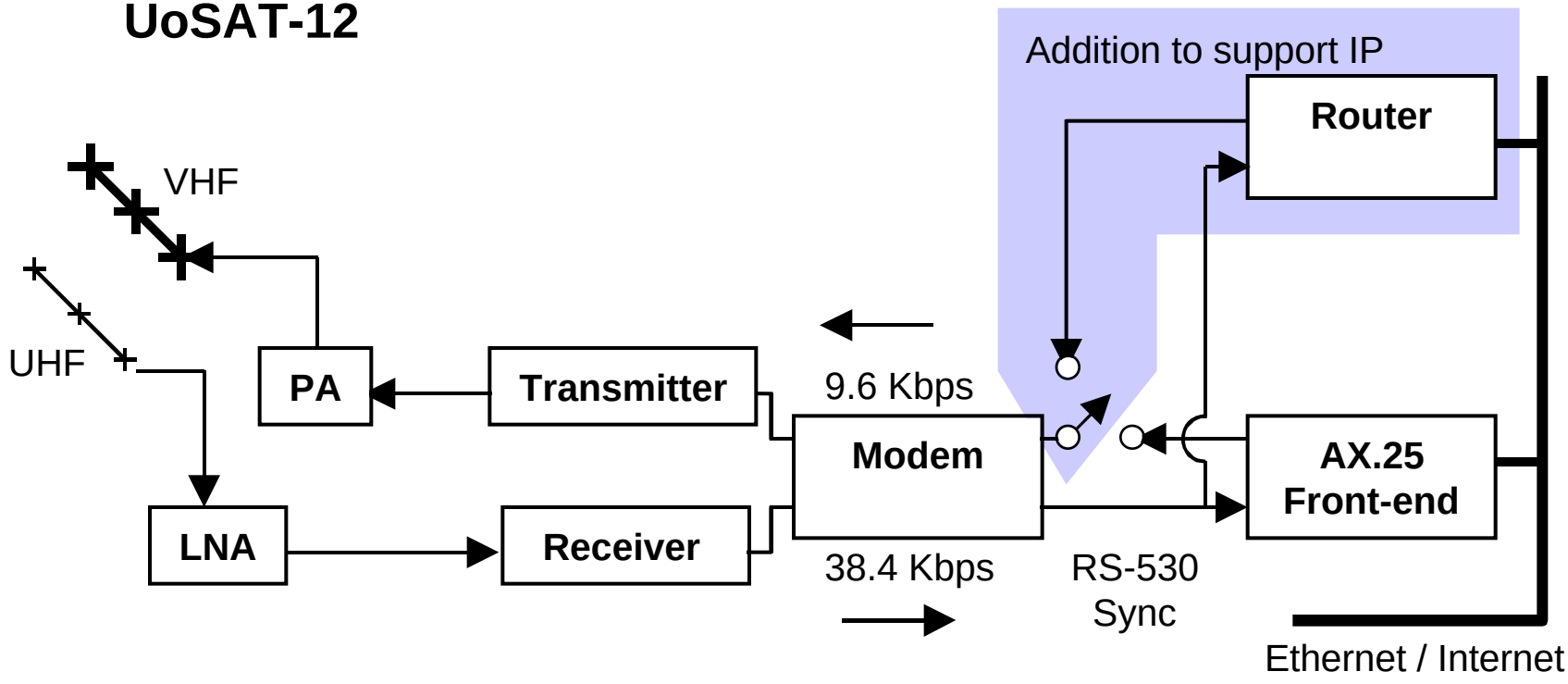
- **UoSAT Microsatellite -- available on the RSDO catalog**
- **UoSAT-12 launched Spring 1999**
- **Owner Surrey Satellite Technology Ltd. (SSTL) (Surrey, England)**
- **LEO**
- **Experimental satellite**
  - Two imaging systems
  - Auxiliary processor
- **UHF and S-band**
- **Single ground station (Surrey)**
- **UoSAT-12 not designed for IP communications**

UoSAT-12 Flight Software Modifications

- **UoSAT-12 Flight Software (VyTek Wireless)**
  - SpaceCraft Operating System (SCOS) developed by VyTek
  - FreeBSD 4.4 IP stack integrated with SCOS and HDLC driver
    - Basic stack supports IP, ICMP, UDP, TCP
  - PING supported via ICMP/IP
  - Network Time Protocol (NTP) client ported to SCOS
    - NTP/UDP/IP
  - File Transfer Protocol (FTP) server ported to SCOS
    - FTP/TCP/IP
- **Cisco router tested with SCOS simulator system in Pittsburgh**

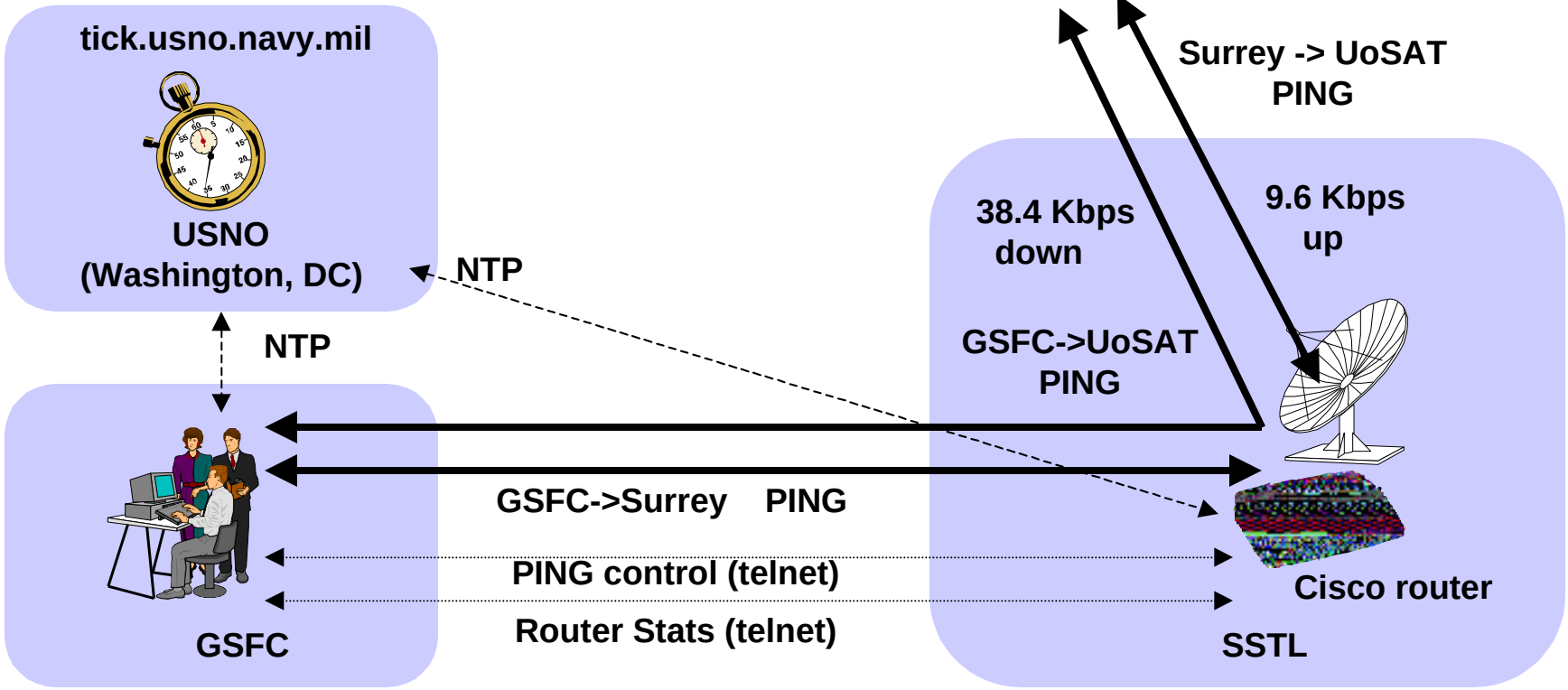
Surrey Ground Station Modifications

- **Surrey Ground Station (SSTL)**
  - Installed Cisco-provided router with RS-530 interface at SSTL
  - Interfaced router to clock/data from SSTL transceiver
  - Verified router receiving HDLC frames
- **Uploaded new SCOS modules to secondary CPU onboard UoSAT-12**



Network Connectivity Configuration

- Continual PING from router to UoSAT-12
- GSFC to Surrey router PINGs (10 sec.)
- GSFC to UoSAT-12 PINGs (10 sec.)
- Router monitoring from GSFC



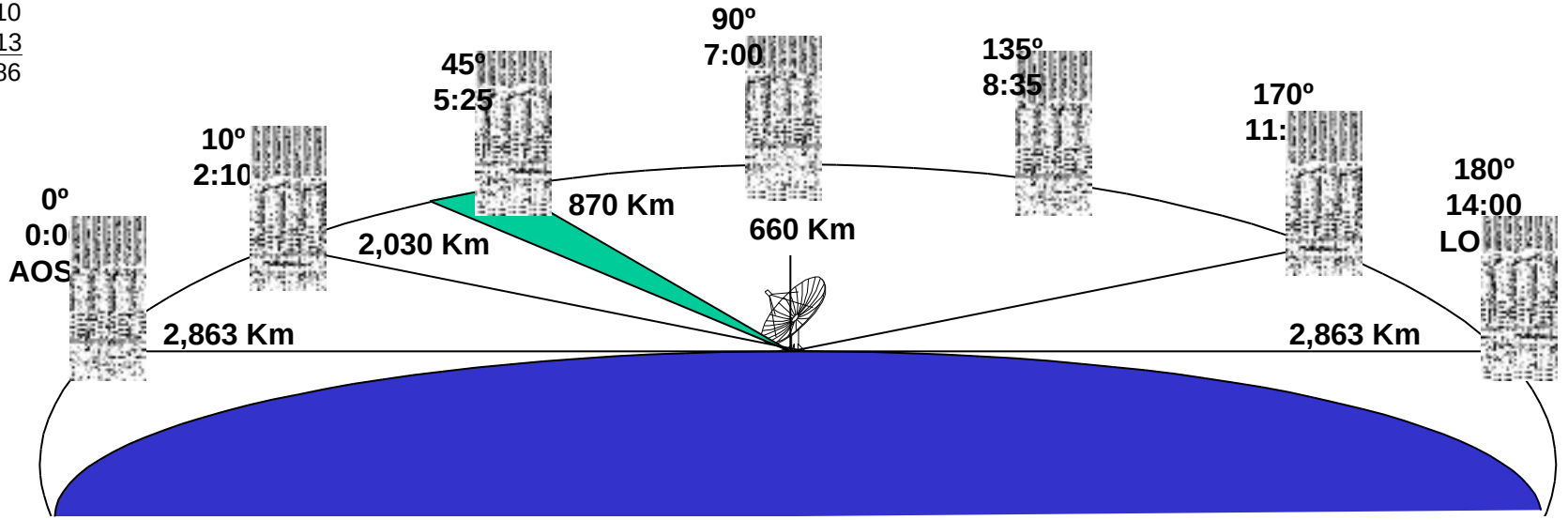
UoSAT-12 Pass Characteristics

- **Propagation delays are a function of data rate and distance**

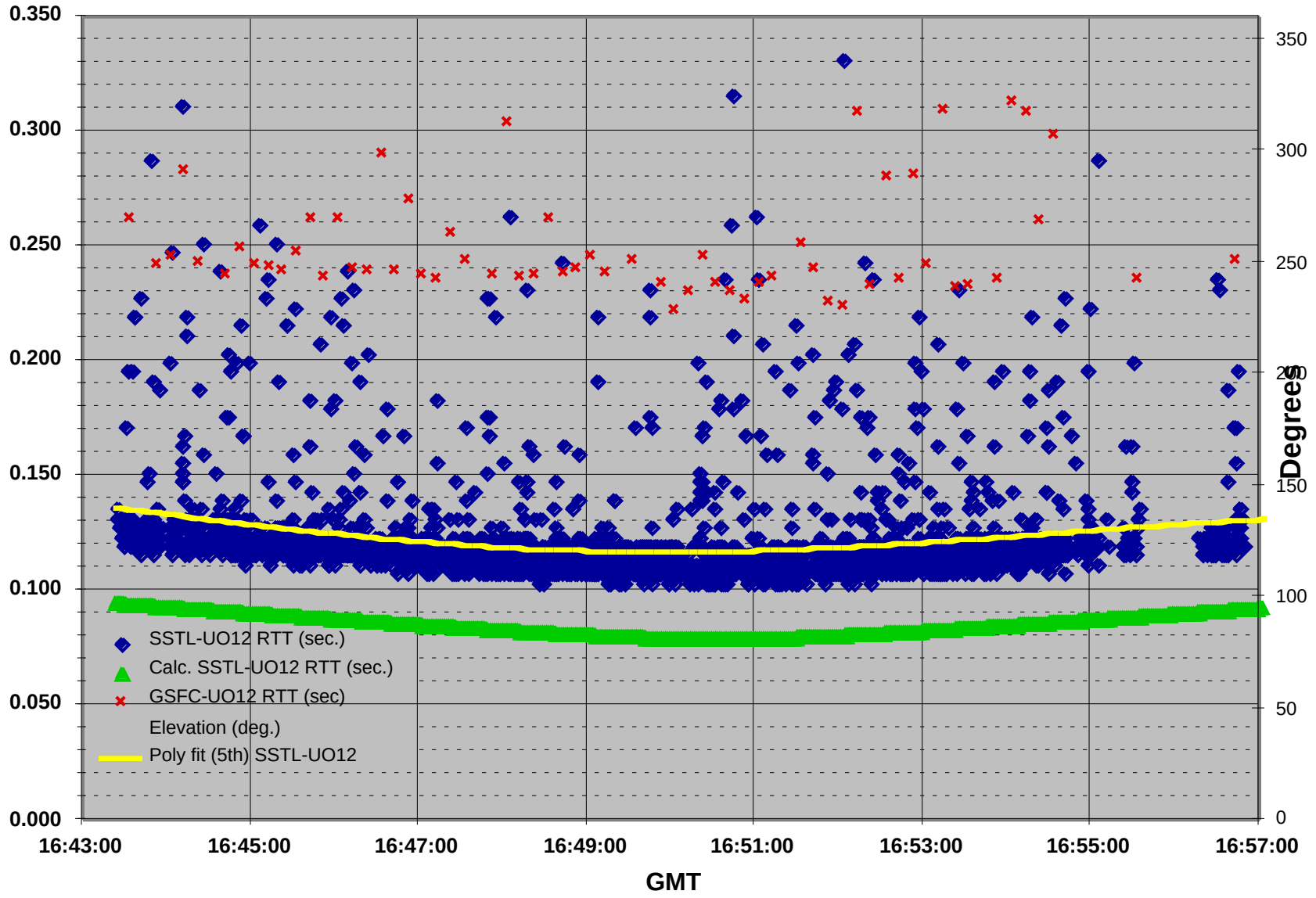
Pkt. Size / Rate	9.6	38.4
64 byte (ms.)	53	13
1280 byte (ms.)	1,067	267

Data Path / Elevation	0º	10º	45º	90º
One-way delay (ms.)	10	7	3	2
64B packet round-trip (ms.)	86	80	72	70
1280B packet round-trip (ms.)	1,354	1,348	1,340	1,338

53
10
10
+13
86

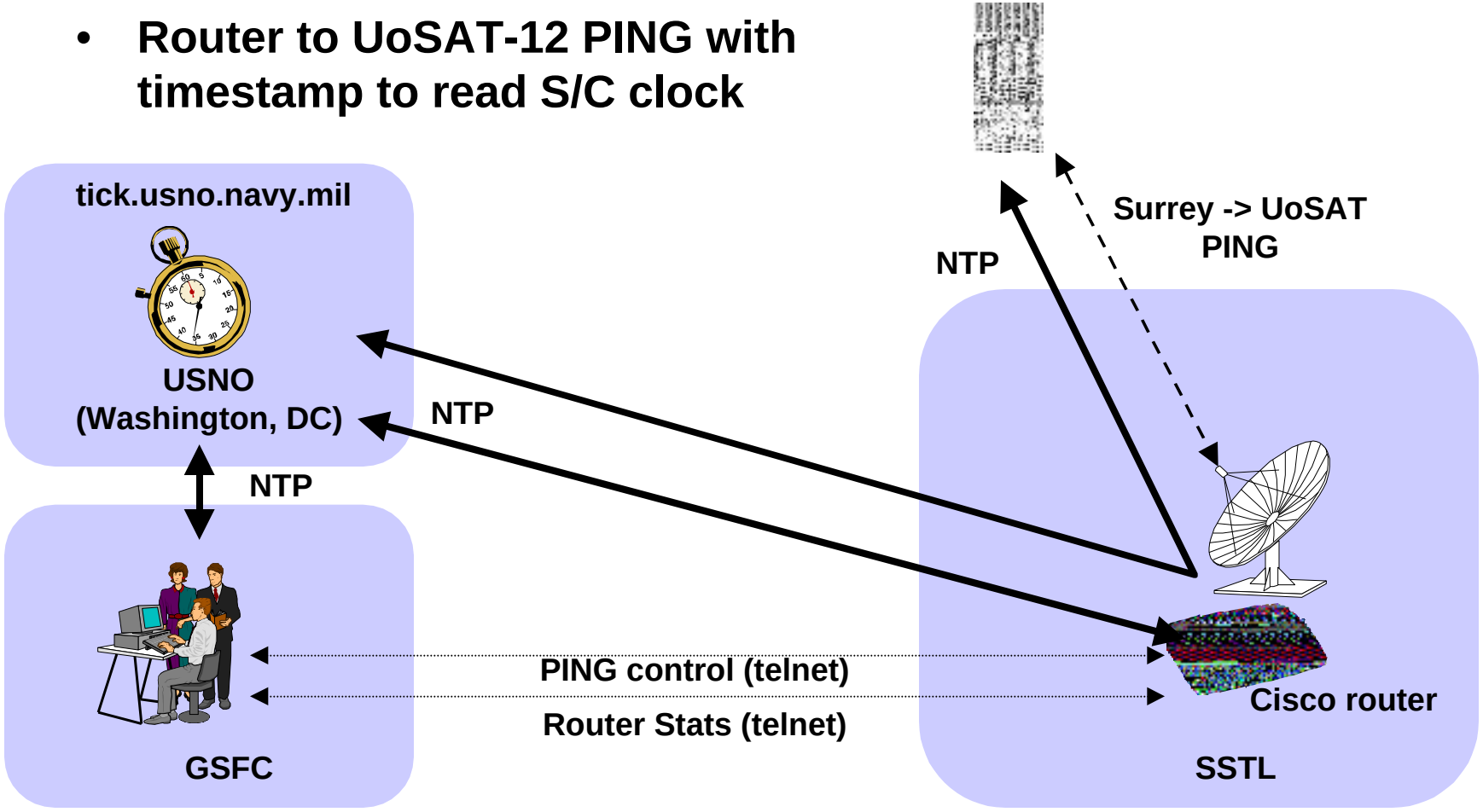


PING Test 2 - 16:43 - Apr. 10, 2000

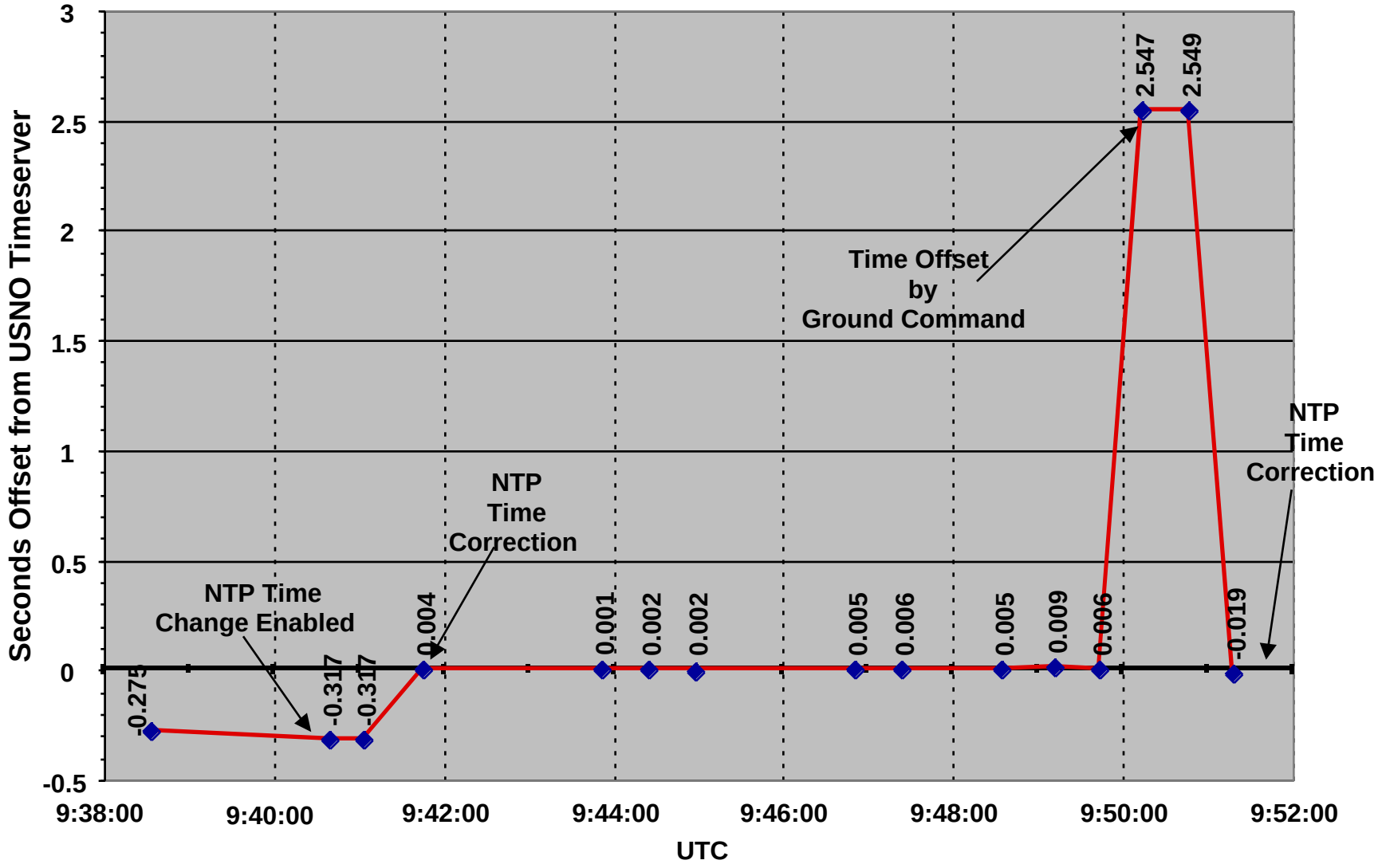


Clock Sync Configuration

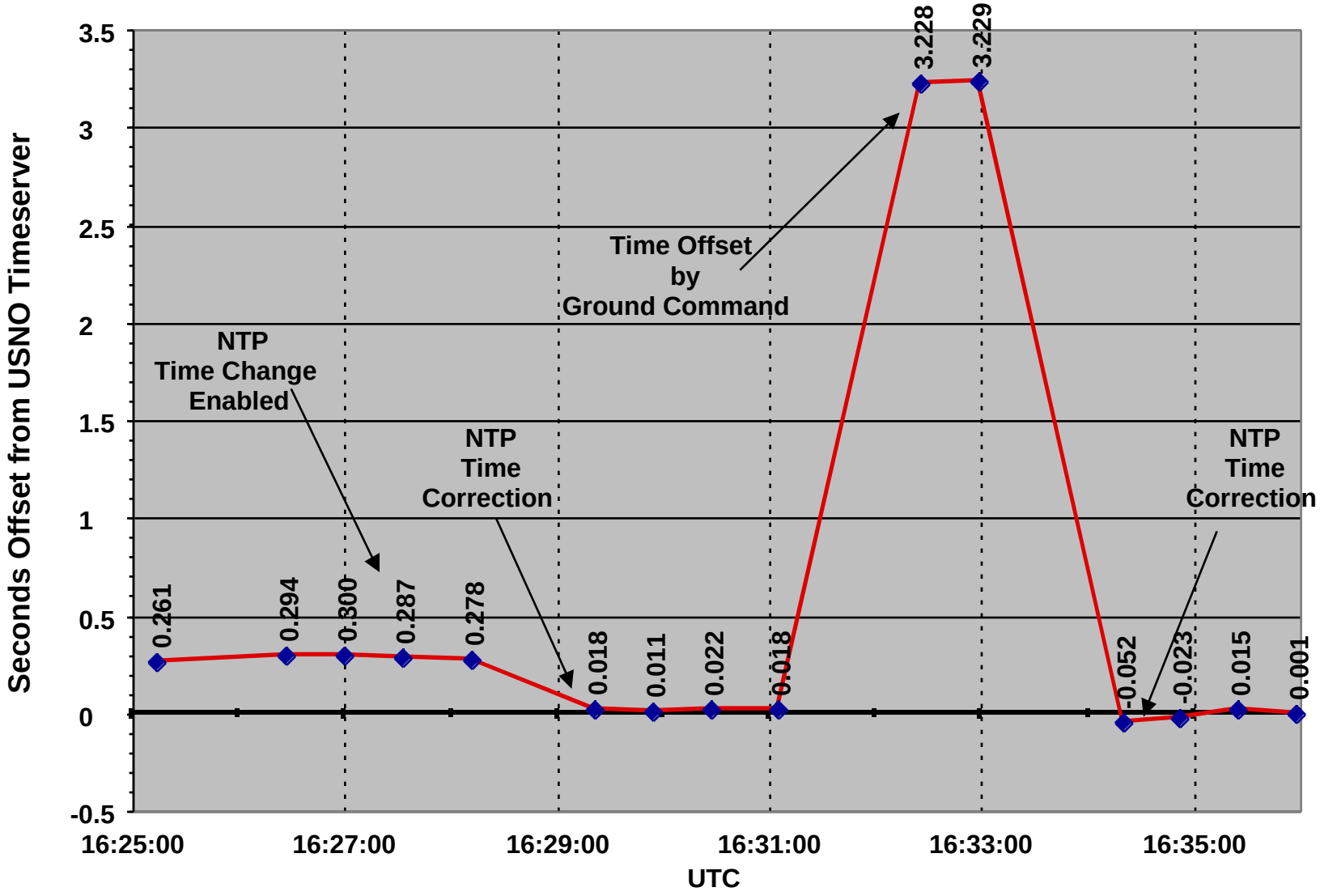
- NTP on UoSAT-12 to sync S/C clock
- Router to UoSAT-12 PING with timestamp to read S/C clock



NTP Test 1 - 09:38 - Apr. 14, 2000

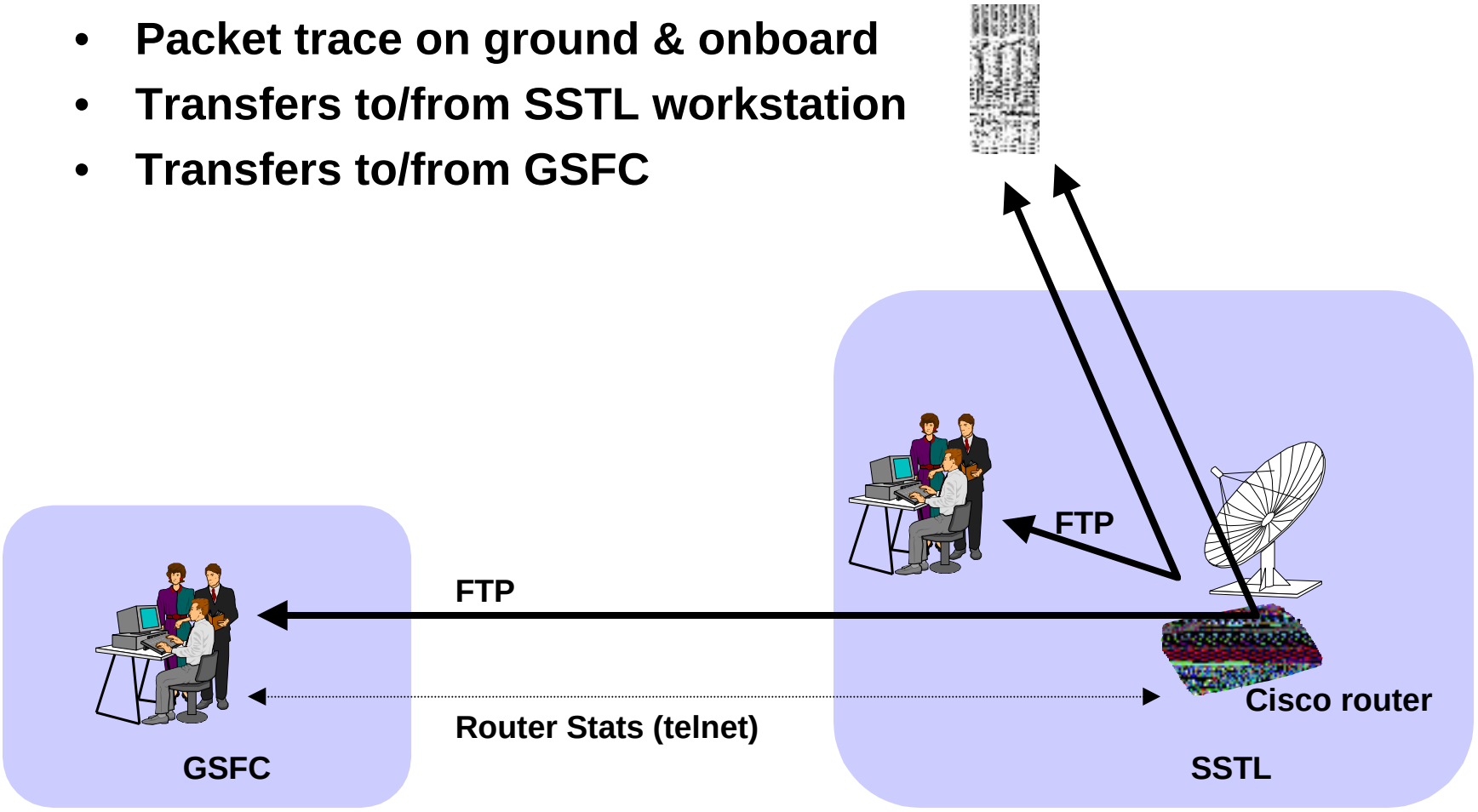


NTP Test 2 - 16:25 - Apr. 14, 2000



FTP Configuration

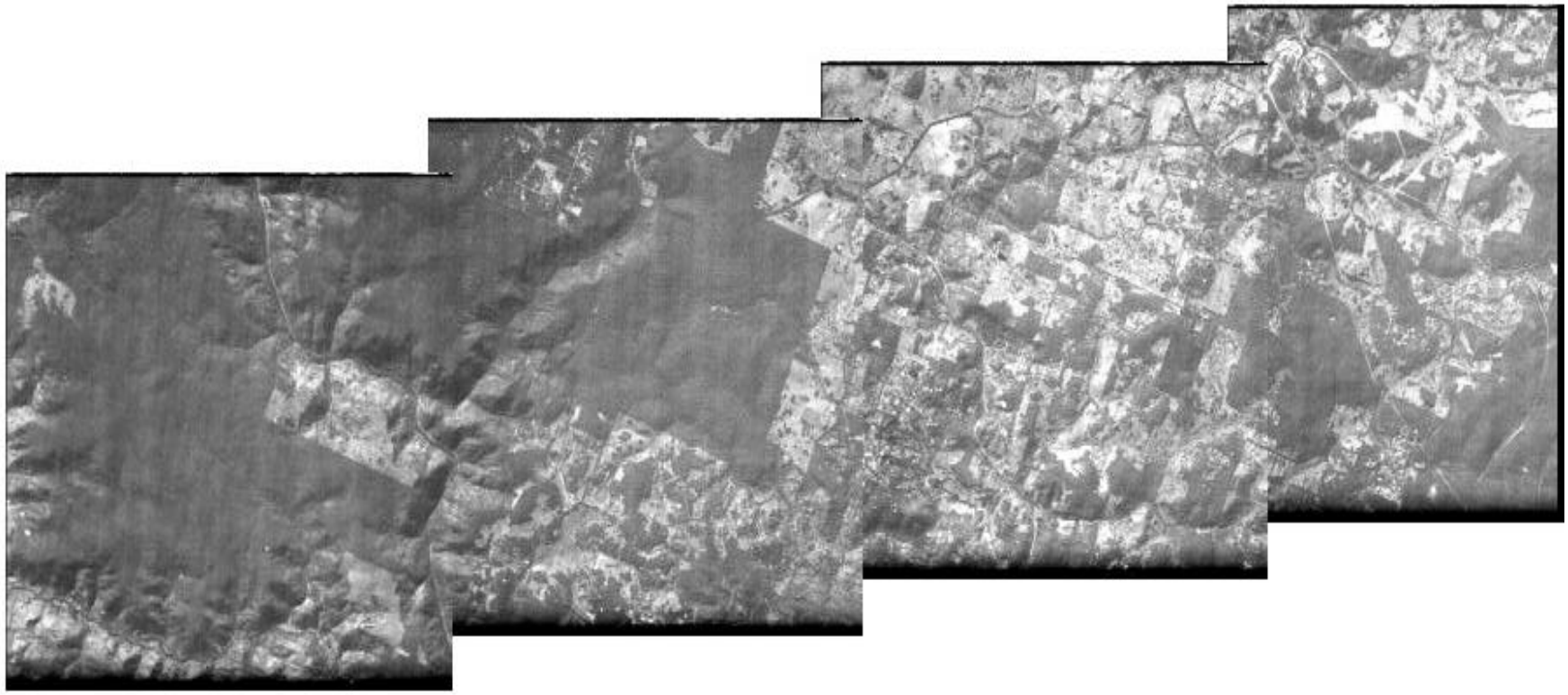
- FTP server on UoSAT-12
- Packet trace on ground & onboard
- Transfers to/from SSTL workstation
- Transfers to/from GSFC



FTP Test 3 - June 7, 2000

- **FTP direct from GSFC to UoSAT-12**

Downloaded 4-Image Mosaic of Perth, Australia



FTP Performance Tuning

- **Analyzed initial FTP traces to identify reason for transmission pauses of 40-60 seconds**
- **Main performance limitation traced to combination of:**
  - 512 byte MTU
  - 2048 byte window
  - 64 second max for retransmit timer
- **Adjusted max retransmit time to 3 seconds and repeated FTPs**
- **Successful data file and image transfers up and down**
  - FTP theoretical application bandwidth is 91.6% of link
    - (512 bytes of data with approximately 50 bytes of HDLC/IP/TCP headers)
  - Uplink: 16.4 KBytes, 8.66 Kbits/sec (with 0 retr.), 90.2% util.
  - Downlink: 227 KBytes, 30.4 Kbits/sec (with 9 retr), 79.2% util.

UoSAT-12 Experiment Conclusions

- **Standard RFC-compliant protocols and hardware upgrade for this LEO mission at existing ground station provided:**
  - Network connectivity and interoperability
  - Onboard clock synchronization within onboard clock and processor time-slice limitations
  - Reliable file transfers
  - A mechanism for reliable delivery of commands to onboard subsystems
- **Existence proof: Some spacecraft can achieve Internet connectivity with minimal hardware (upgrade) at ground stations**
- **Tuning of TCP stack parameters can raise performance in TCP-based data transfers for LEO spacecraft**

Future OMNI/UoSAT-12 IP Experiments

- Real-time data delivery (UDP)
- Reliable commanding (TCP) and blind commanding (UDP)
- Multicast real-time data delivery (UDP/IP multicast)
- UDP-based, asymmetric bandwidth, “reliable” file transfer (MFTP, CFDP, PBP, etc.)
- Automatic routing at multiple ground stations (Mobile IP)
- Automated file store and forward (SMTP)
- Network security (VPN at ground sites and spacecraft)

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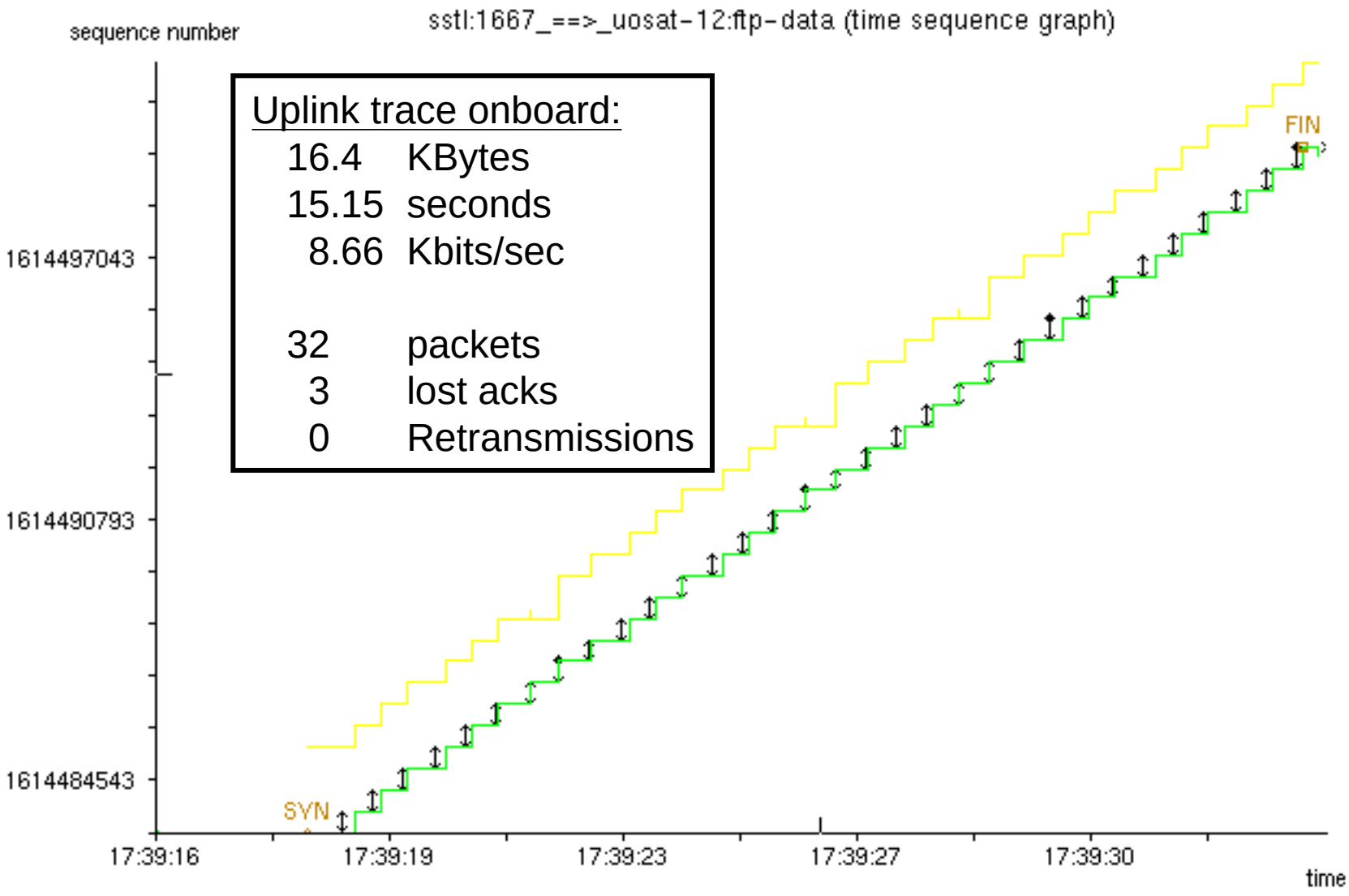
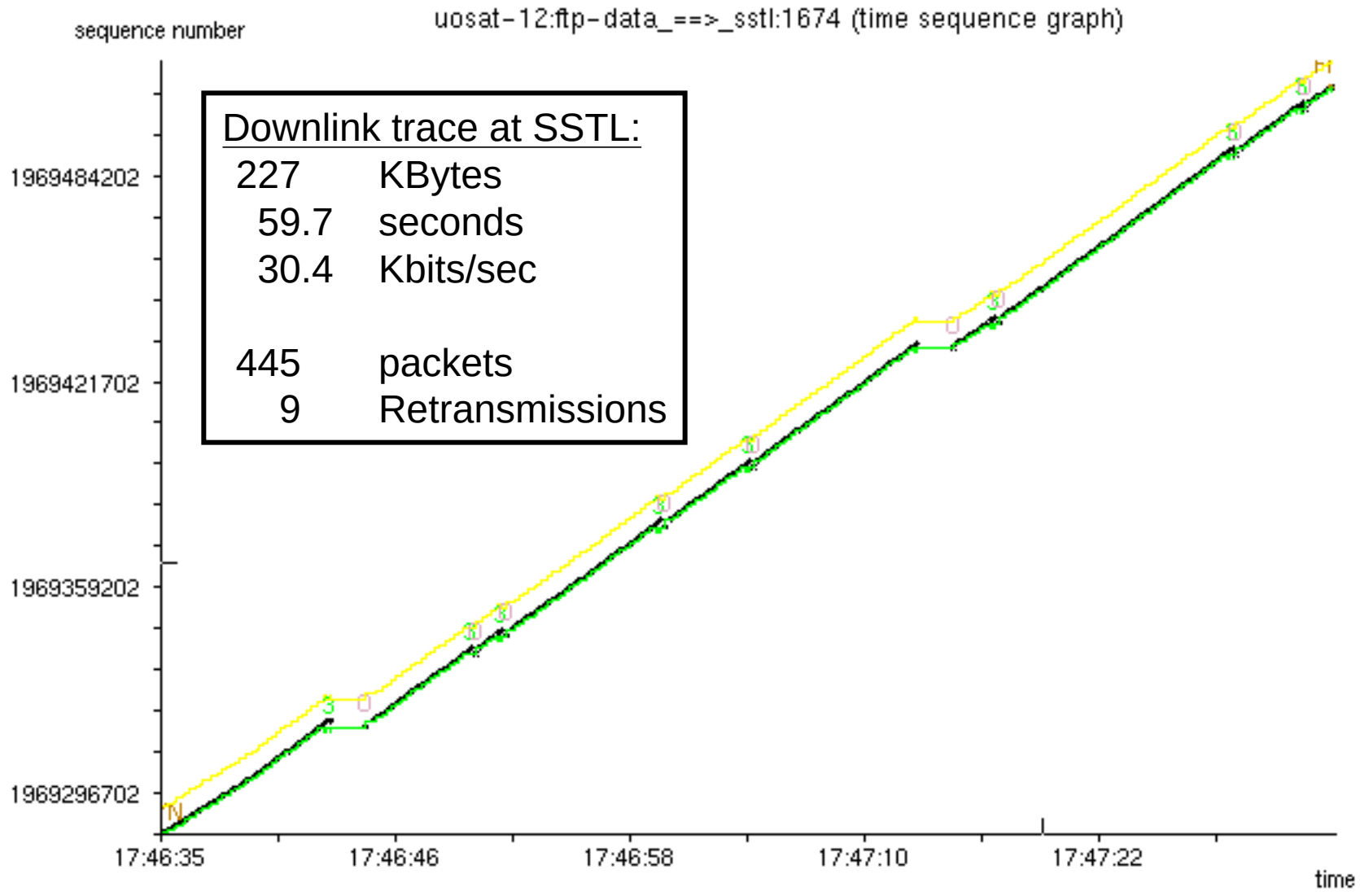
FTP Test 7 - July 5, 2000



Uplink trace onboard:

16.4	KBytes
15.15	seconds
8.66	Kbits/sec
32	packets
3	lost acks
0	Retransmissions

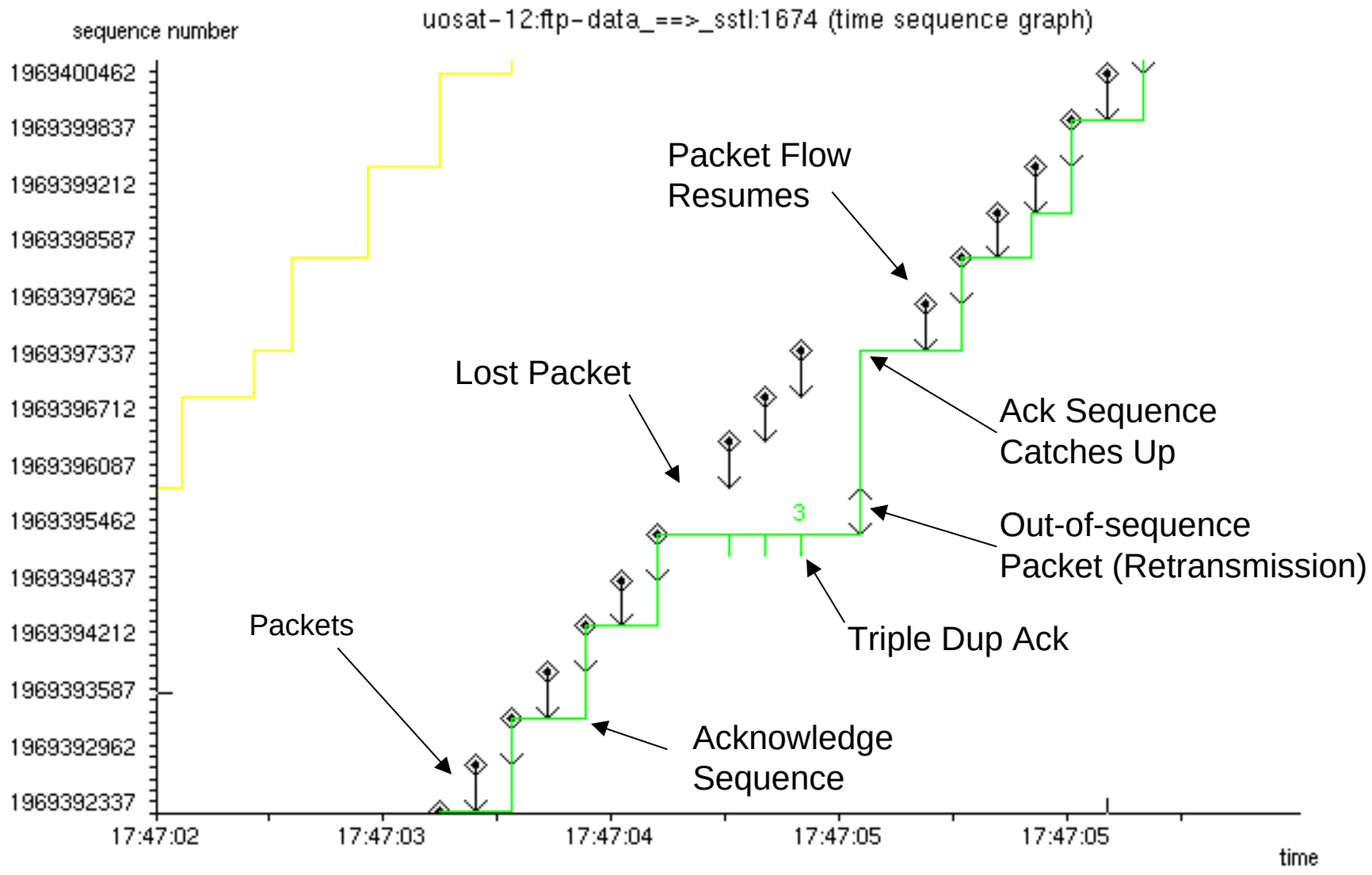
FTP Test 7 - July 5, 2000



Downlink trace at SSTL:

227	KBytes
59.7	seconds
30.4	Kbits/sec
445	packets
9	Retransmissions

FTP Rapid Retransmit



FTP: Retransmit Timeout